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The Scottish Cod Fishery in the North Sea

By D. F. S. RAITT and D. J. SYMONDS

Marine Laboratory, Aberdeen

June, 1967

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The Scottish Cod Fishery in the North Sea

INTRODUCTION

The cod is one of the most important commercial food fishes caught in the North Sea. Parrish (in Graham, 1956) has comprehensively reviewed the available literature on the cod of the north-east Atlantic, including the North Sea, but the work and results which he describes from this latter area are almost entirely concerned with the southern and central North Sea. There is very little published information on the cod stocks exploited by Scottish fishermen or on the extent and size of the Scottish northern North Sea cod fishery.

The purpose of this paper is to describe the Scottish fishery and the changes which have occurred in it over the years and to assess the present state of the northern North Sea stock.

SOURCES OF INFORMATION

Several published and unpublished sources of information on cod catches and fishing effort in the North Sea have been utilised in the preparation of this report. These are as follows:—

(1) Bulletin Statistique des Pêches Maritimes. These statistics are published annually by the International Council for the Exploration of the Sea and give information on the landings (nominal catches) from each of the I.C.E.S. regions (including the North Sea) for each country.

(2) Scottish Sea Fisheries Statistical Tables. These have been published annually since 1882 but until 1954 they gave information only on the quantities of fish landed. In 1955 and subsequent years more detailed data on the landings and fishing effort involved have been given.

(3) Unpublished Tabulations.

(*a*) *Fishery Board for Scotland, North Sea Investigations.* These are hand-written ledgers, and although much of the information was used in compiling the early Scottish Sea Fisheries Statistical Tables, they are unpublished. They give information on the landings and fishing effort from all areas, from the early 1900's to 1953, for Aberdeen steam and motor trawlers. (Also available, but not used, are similar statistics for Granton trawlers.)

(*b*) *D.A.F.S. Tabulations.* The market statistics collected by Scottish Fishery Officers have been computer tabulated since 1955, first by the Scottish Home Department and later by the Department of Agriculture and Fisheries for Scotland, and these tabulations give detailed analyses of the catch and effort of all types of Scottish vessels.

In addition to handling statistics of landings and fishing effort, the Marine Laboratory in 1963 began a programme of market sampling of North Sea cod at Scottish fishing ports. Length and age data have been collected on Aberdeen fish market by members of the laboratory staff and by fishery officers on the fish markets at Granton, Newhaven, Fraserburgh, Lossiemouth and Buckie. Ages are determined from the otoliths, which are extracted on the fish market from underneath the gill cover so that the market appearance and value of the fish are not affected. Routine data obtained from this sampling programme are published annually in the I.C.E.S. Statistical News Letter series and in the U.K. Fish Stock Record.

THE IMPORTANCE OF THE SCOTTISH NORTH SEA COD FISHERY

The total weight of cod landed at Scottish ports by British vessels fishing in the major areas from 1924 to 1965 are shown in Figure 1. Since 1924 approximately one half of all cod landed have come from the North Sea, one-quarter from Faroe, one-eighth from the west coast of Scotland and smaller quantities from Iceland, Bear Island, Greenland, Rockall and the Irish Sea.

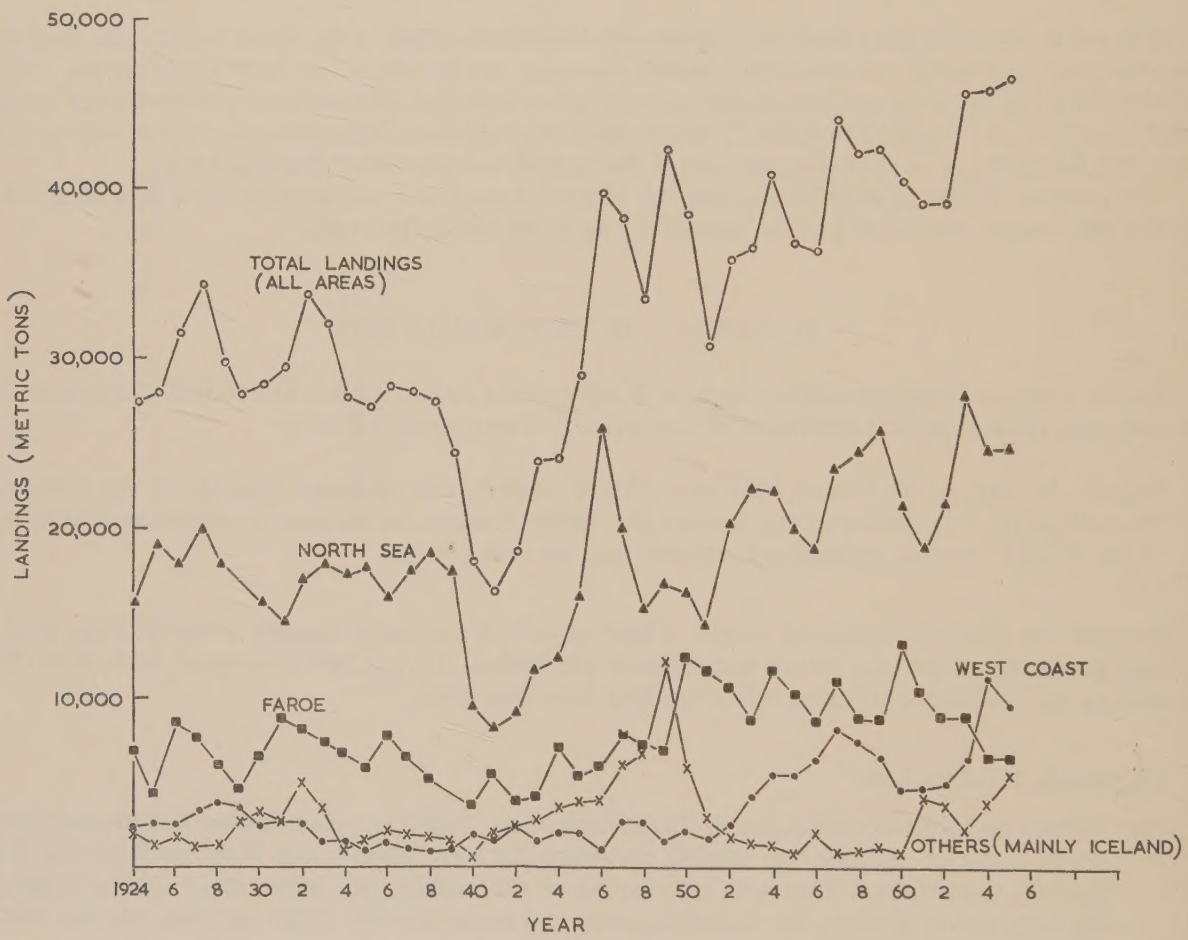


Fig. 1. Total Scottish cod landings from all areas, 1924-65.

The cod is one of the five most important fish landed by Scottish fishermen. The other four are haddock, herring, whiting and plaice. The total landings of each of these species from the North Sea in the years 1951-1965 are shown in Figure 2a. Although the annual landings of haddock and herring have fluctuated very widely from about 30,000 to 80,000 tons, cod and whiting have been relatively steady at between 20,000 and 40,000 tons, the whiting landings being in general rather higher but the cod landings generally increasing. Plaice landings have varied very little from an average of 5,000 tons per year. The values of these landings are shown in Figure 2b. Since 1957, cod has been the second most important fish landed, only haddock having a higher total value. In fact, the average price of cod per cwt has risen steadily from 54s in 1951 to 84s in 1965.

Landings of cod from the North Sea by various countries since the Second World War are given in Figure 3. The total landings by all countries have shown wide fluctuations; they decreased from 110,000 tons in 1946 to about 60,000 tons in 1951 and then rose steadily to 180,000 tons in 1965. In fact the landings from

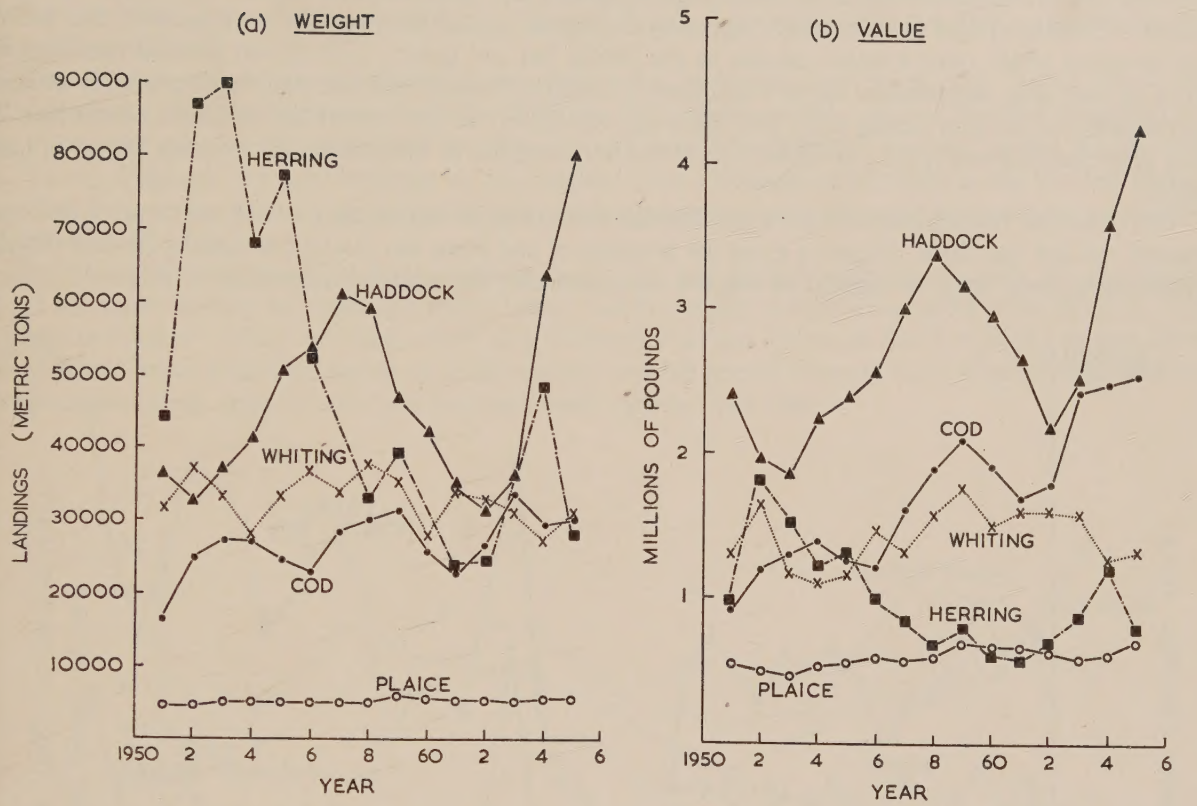


Fig. 2. (*a*) Total weight, (*b*) total value of the most important fish species caught by Scottish fishermen in the North Sea, 1951–65.

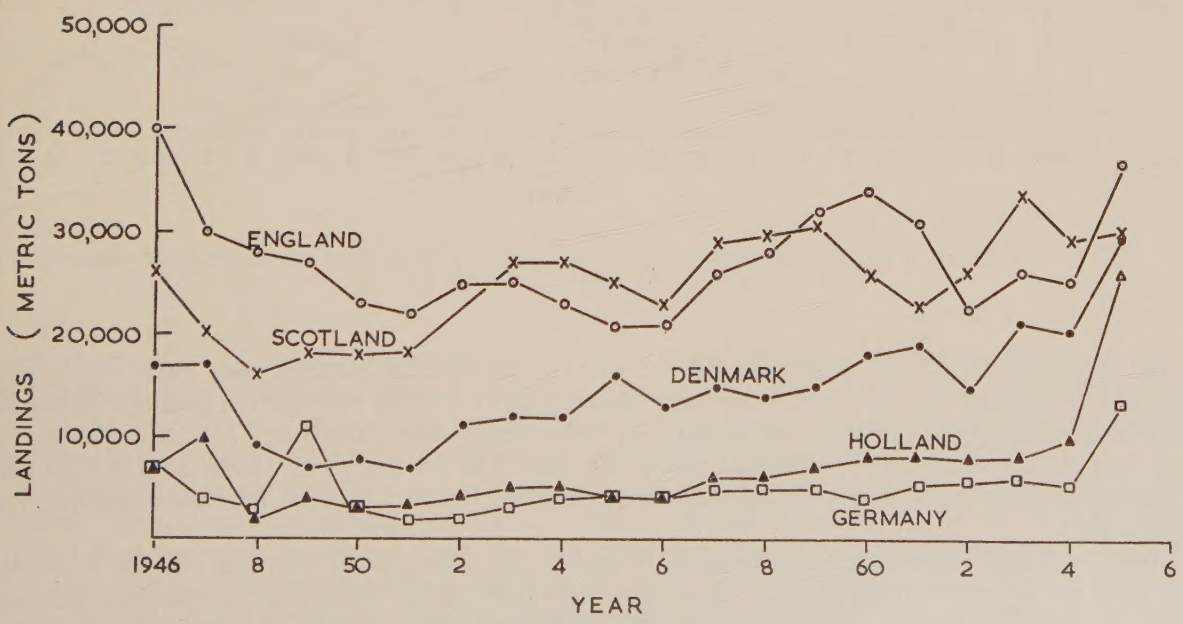


Fig. 3. Total landings of cod from the North Sea by various countries, 1946–65.

the North Sea have almost trebled in fifteen years. England and Scotland have landed approximately 60% of the total, this being shared fairly equally (especially during the 1950s) between the two countries. The landings of all countries which have a major interest in the North Sea cod fishery have shown gradual increases since 1951. The very large increases in 1965 for England, Denmark, Holland and Germany were probably associated with the entry of the very strong 1963 year-class into the fishery in the central and southern North Sea. This strong year-class did not appear in abundance in the northern North Sea, where the Scottish fishery is mainly centred.

The principal fishing methods used by Scottish fishermen in exploiting the cod stocks are trawl, seine, anchored cod-net and lines. Figure 4 gives the landings of cod from the North Sea area by British vessels at Scottish ports since 1924 by method of capture. It shows that the relative importance of different gears has

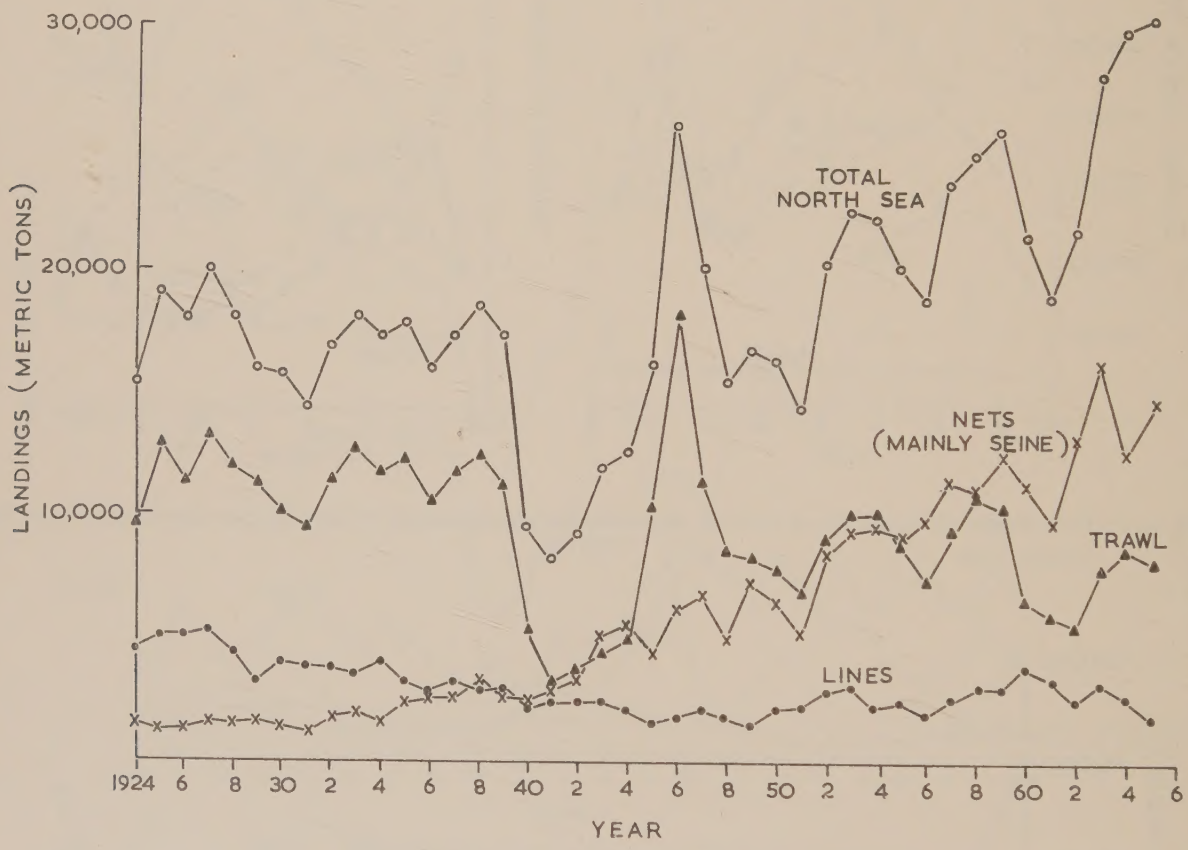


Fig. 4. Comparison of Scottish cod landings from the North Sea by different fishing methods, 1924–65.

changed markedly during this period. In the pre-war period the total landings were fairly steady between 15,000 and 20,000 tons per year, and were mostly taken by trawl. During this time the landings by line vessels were gradually falling off, and while the landings by 'other nets' (mainly seines and cod nets) were increasing slowly they did not amount to a substantial part of the total. The war years saw a large drop in total landings but this was almost entirely due to the decrease in trawling, the landings by other methods remaining at about the same level.

After the initial rapid increase in landings to 26,000 tons immediately after the war the total landings dropped to around 15,000 tons in 1951. Since then they have shown fairly wide fluctuations, although the general tendency has been for them to increase. During this same period the trawl landings have on the whole been smaller than before the war and have decreased slowly, whereas the landings by 'other nets' (which have

consisted almost entirely of seine nets) have shown a marked upward trend, and since 1955 have landed more cod from the North Sea grounds per year than the trawl fishery. Line fishing has also shown a slight but steady increase since the war.

The development of the Scottish seine-net fishery has been described by Ritchie (1960). The gradual modernisation of the Aberdeen near-water trawling fleet from steam vessels to motor trawlers intensified in the early 1950s and was virtually completed by 1960. A more recent development has been in the introduction of light trawls. Although the total landings by this method have increased significantly in the last few years and a separate category has been set up in the Scottish tabulations, in the data reviewed here they have been included with the seine-net landings.

More detailed statistics have been available since 1955 and annual estimates of catch per unit effort (in cwt per 100 hours' fishing for steam and motor trawls, and in cwt per 10 days' absence for seine and line catches) are given in Figure 5. These estimates cover only a short period but it appears that the catch per unit effort of both lines and seines have been steady or rising slightly over the period, whereas those of both steam and motor trawl decreased from 1958 to 1961 and have increased slightly since then.

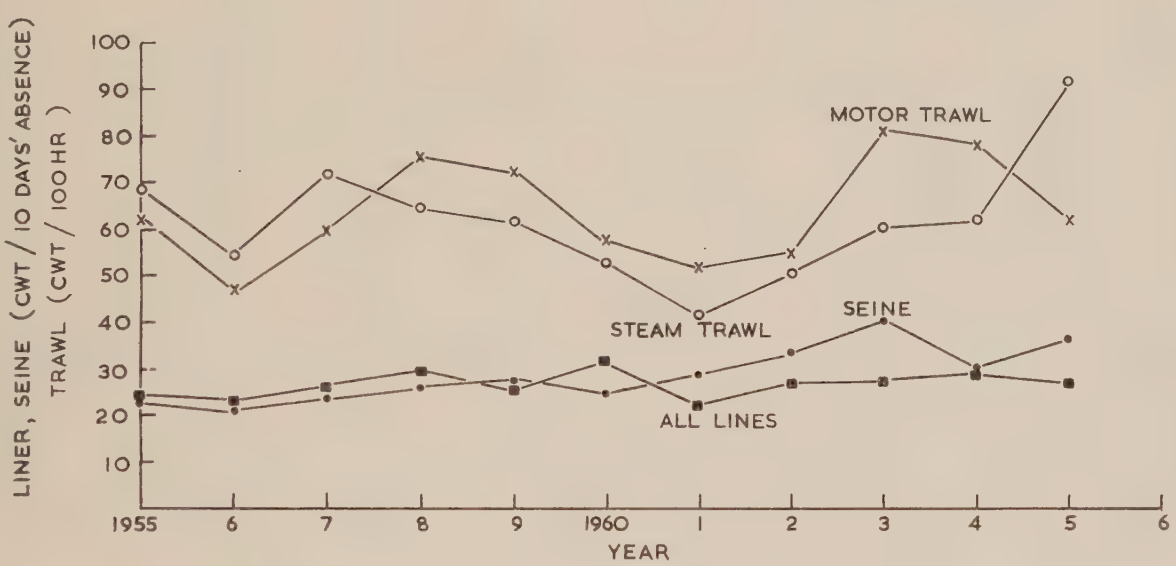


Fig. 5. Scottish catch per unit effort for different fishing methods, 1955–65.

DISTRIBUTION OF FISHING

For the purposes of the market sampling programme, started in 1963, the northern North Sea was subdivided into six areas. These are shown in Figure 6 together with some of the more important cod fishing grounds. The importance of each area in terms of weight of cod landed and the fishing effort involved in the years 1959-1965 is shown separately for trawlers and seine-net vessels in Tables I and II.

The Scottish seine-net fishery for cod in these years was centred mainly in the Moray Firth and East Coast and Orkney areas, these areas yielding about 80% of the cod landed by seine-net. For the trawlers, which are prohibited from fishing in the Moray Firth, the East Coast and Orkney area was again a major centre of cod fishing, over half the total landings being caught in this area. In addition, about one-quarter of trawl-caught cod came from the North Coast area. Thus the Scottish fishery for cod in the North Sea is largely concentrated around the coastal regions of the Scottish mainland.

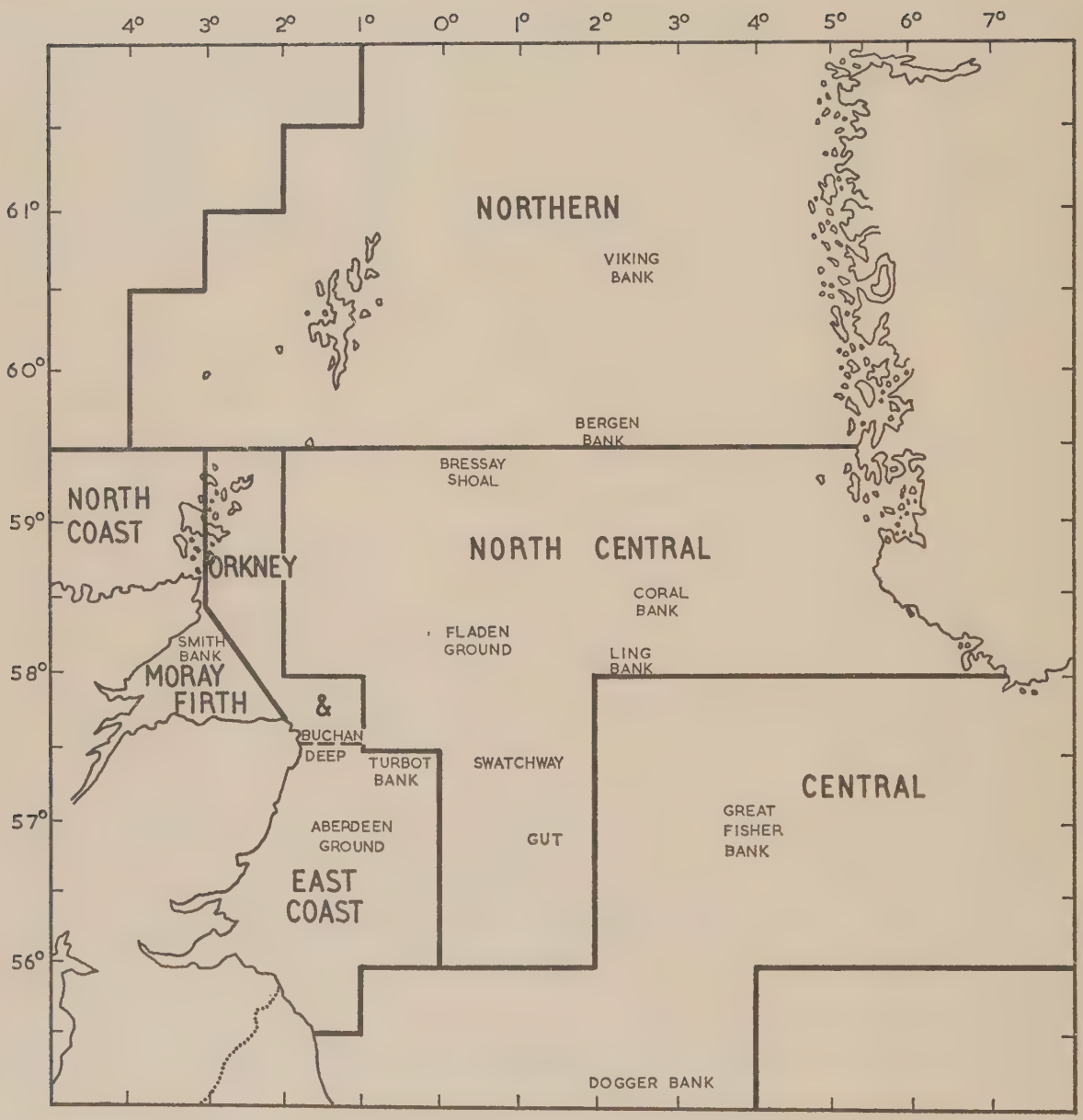


Fig. 6. Laboratory market sampling areas in the North Sea and the main cod fishing grounds.

TABLE I

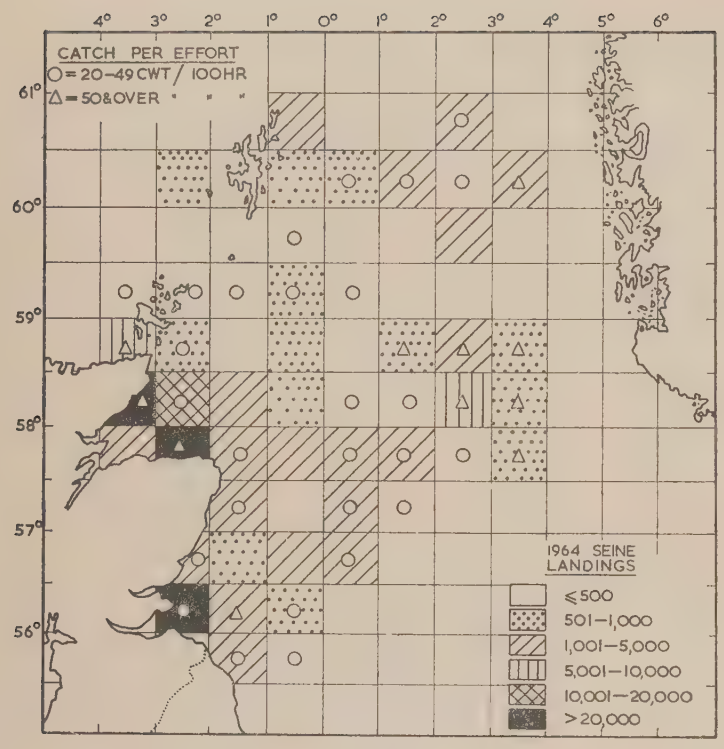
SCOTTISH LANDINGS AND FISHING EFFORT FOR ABERDEEN TRAWLERS WORKING IN THE NORTH SEA

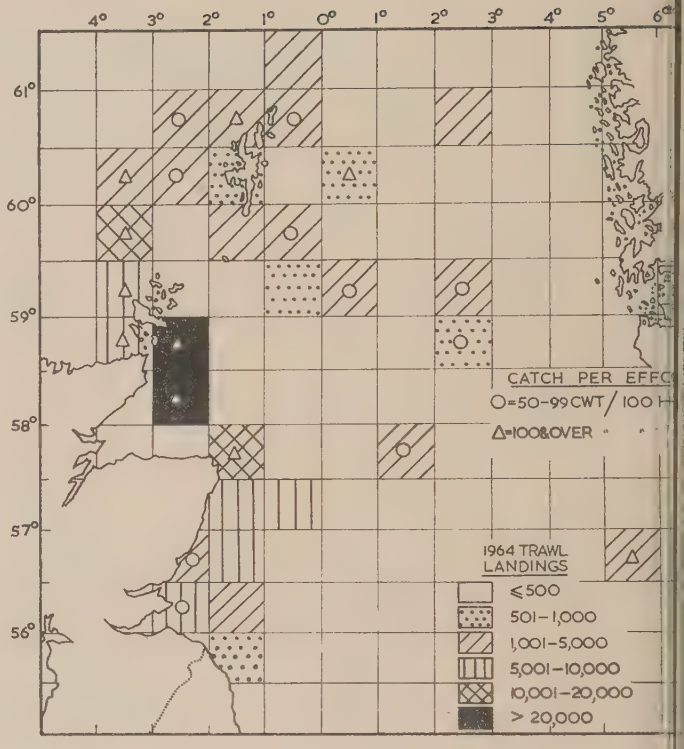
		North Coast	East Coast and Orkney	Northern		North Central	Central	All Areas
1954	tons		6077		2029		108	8214
	hours		182571		63880		1714	248165
1955	tons		5072		2178		3	7253
	hours		163133		67218		234	230385
1956	tons		4185		1707		1	5893
	hours		147628		57605		60	205293
1957	tons		5593		1447		8	7048
	hours		139021		48945		262	188228
1958	tons		4870		2379		9	7258
	hours		135505		87154		193	222852
1959	tons		3772	1382		624	17	5795
	hours		96366	67540		22788	638	187332
1960	tons	1323	3310	1052		473	2	6160
	hours	30187	101932	51041		12615	125	195900
1961	tons	1400	3076	929		384	17	5806
	hours	28116	113796	48071		12809	2374	205166
1962	tons	1420	2916	663		347	44	5390
	hours	25384	108772	35356		10272	1726	181510
1963	tons	1336	5050	646		331	36	7399
	hours	22168	113014	25858		6392	2636	170068
1964	tons	3102	5062	1218		166	38	9586
	hours	44478	122347	30322		3560	1834	202541
1965	tons	2450	4618	717		312	38	8135
	hours	45924	110728	18145		8176	1148	184121

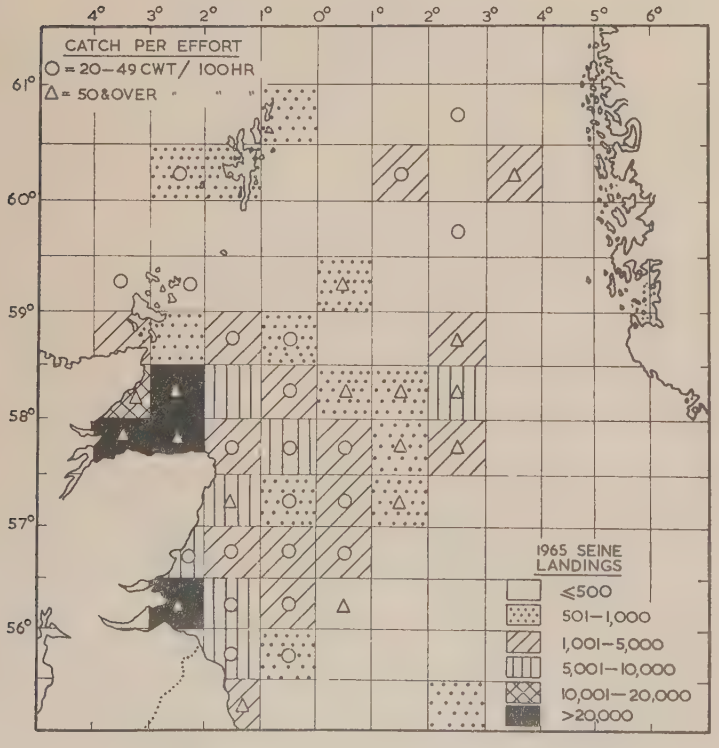
TABLE II

SCOTTISH LANDINGS AND FISHING EFFORT FOR BRITISH SEINE-NET VESSELS WORKING IN THE NORTH SEA

		North Coast	East Coast and Orkney	Northern		North Central	Central	Moray Firth	All Areas
1959	tons		4079		2074		223	5696	12072
	days		22719		23877		1045	36246	83887
1960	tons	574	3884		1140		145	5221	10964
	days	6592	21938		25791		508	36047	90876
1961	tons	486	3096	597		809	84	4787	9859
	days	5244	21285	13892		14236	680	34269	89606
1962	tons	778	4397	492		843	172	7134	13816
	days	3576	22600	11525		11371	896	29583	79551
1963	tons	977	4684	652		1161	54	9275	16803
	days	3590	24074	10912		12187	364	30099	81226
1964	tons	944	3187	717		1602	65	6520	13035
	days	4530	26437	11492		11390	379	29617	83845
1965	tons	495	5126	405		2033	254	6491	14804
	days	5007	27765	8401		11768	740	26455	80136







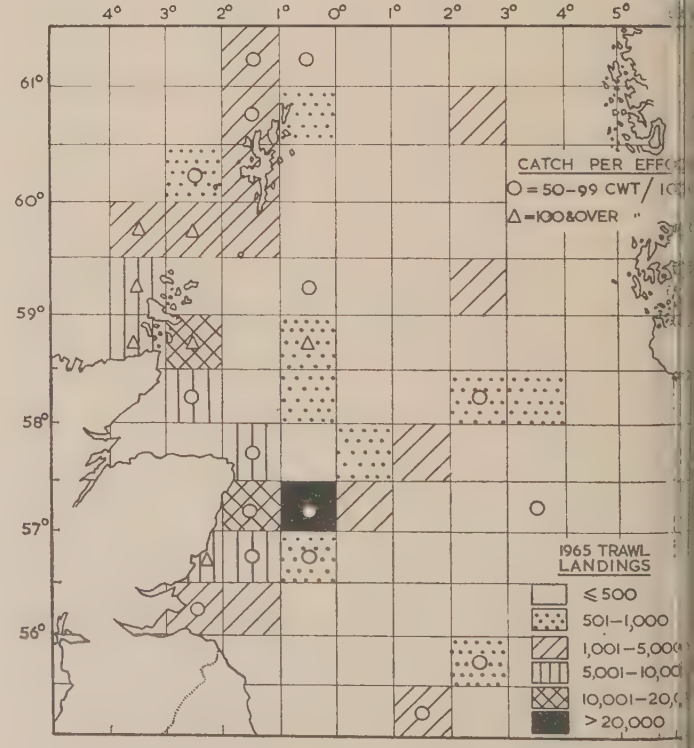


Fig. 7 Total landings of cod in cwt and catch per unit effort by Scottish seiners, 1964 (above) and 1965 (below).

Fig. 8 Total landings of cod in cwt and catch per unit effort by Scottish trawlers, 1964 (above) and 1965 (below).

More detailed charts of the distribution of the cod fishery by statistical squares and of the areas which gave the highest catch per unit fishing effort are shown in Figure 7 (seine 1964 and 1965) and Figure 8 (trawl 1964 and 1965). Seiners caught cod over a wide area of the northern North Sea, though the highest total

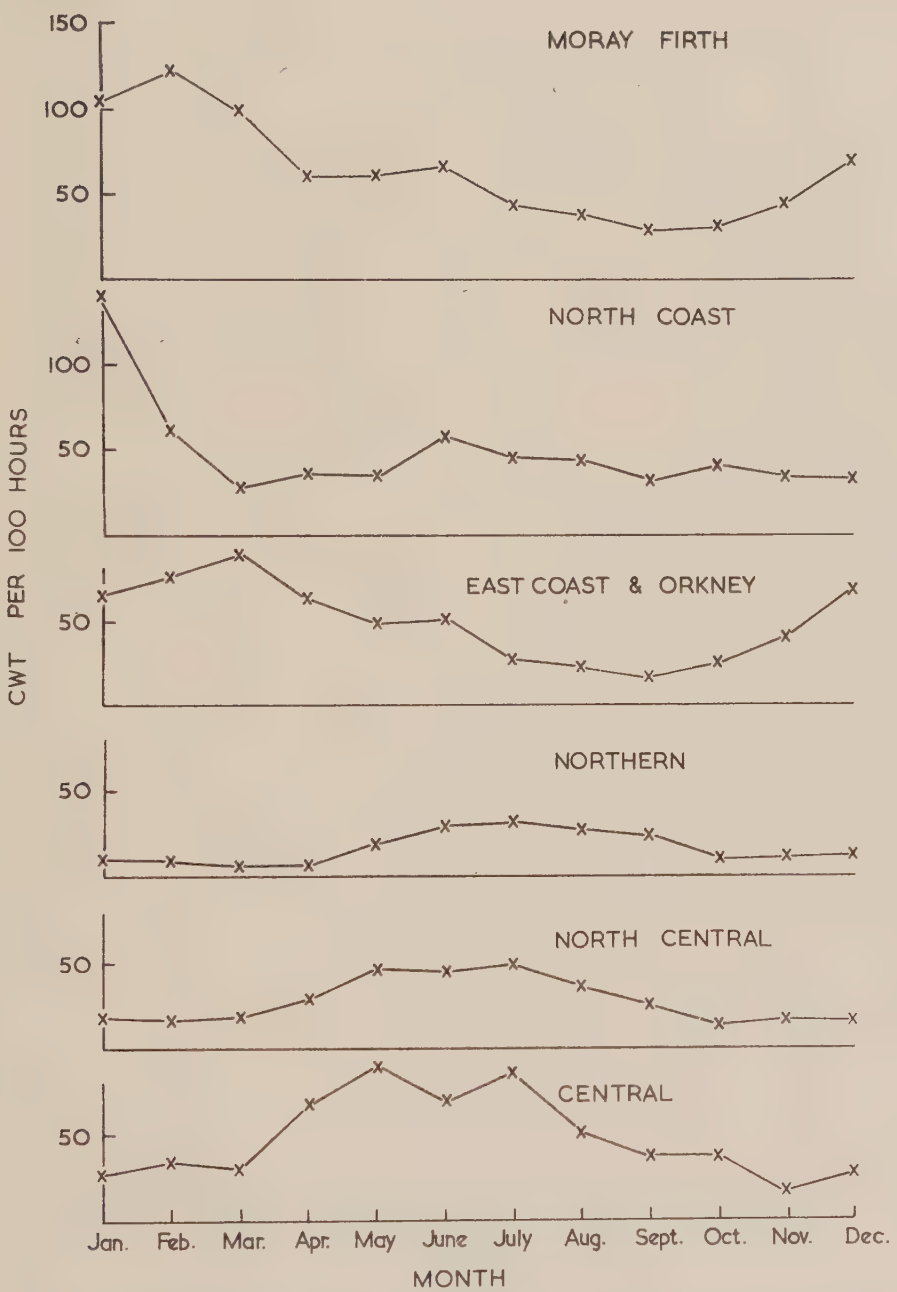


Fig. 9. Seasonal variations in seine-net catching rates from different North Sea areas.

landings came mainly from the inshore grounds in the Moray Firth and off the firths of Tay and Forth. These areas were generally associated with high catching rates. Good landings were also made in both years from the statistical square G15, the area of the Ling and Coral Banks, both good fishing grounds for cod. High catches per unit effort were also obtained in these areas,

When one compares the picture for seiners with that for trawlers it can be seen that, although once again the inshore grounds are the most important, the trawlers had good cod fishing off the north coast and on the Shetland grounds and they did not land so much fish from the offshore North Sea areas.

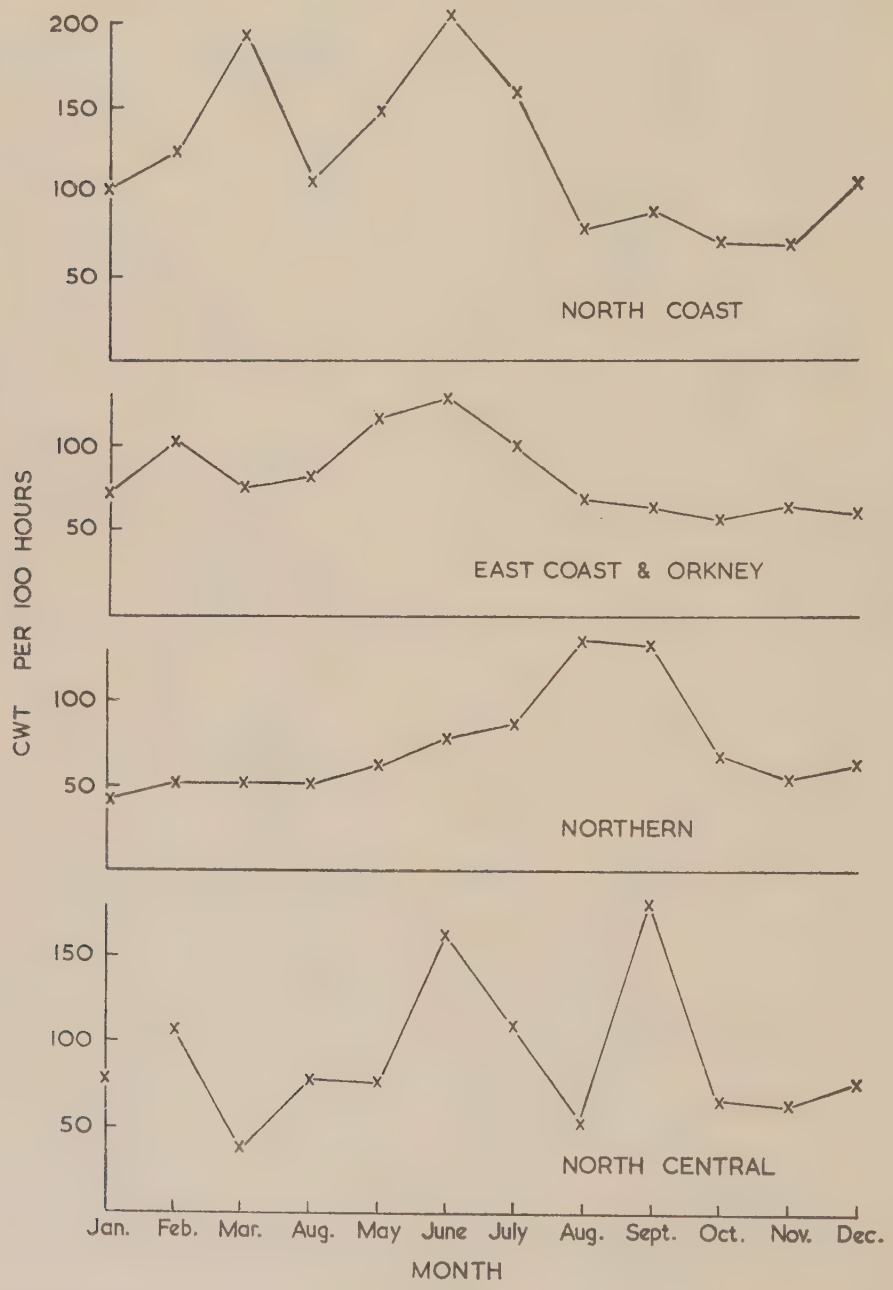


Fig. 10. Seasonal variations in trawl catching rates from different North Sea areas.

It is important to bear in mind, regarding Figures 7 and 8, that cod may often have occurred as a by-catch when the boats were mainly seeking haddock and whiting, so that a high catch figure may not necessarily coincide with an area being one of high cod abundance unless it is associated with a good catch per unit effort. In this context it is also not possible when dealing with a mixed fishery to draw firm conclusions from the slight distributional differences in catches and catching rates between years for the same gear.

The average seasonal variations in the catch per unit effort for Scottish seiners fishing in the main market sampling areas for 1963-1965 (expressed as cwt per 100 hours' fishing) are shown in Figure 9. The three inshore areas, East Coast and Orkney, Moray Firth and North Coast all show clearly that the best catching rates occurred in the winter months, December to March. This is the spawning season for cod in the northern North Sea. The results for the offshore areas, however, show the lowest catching rates during the winter months and the best from May to September.

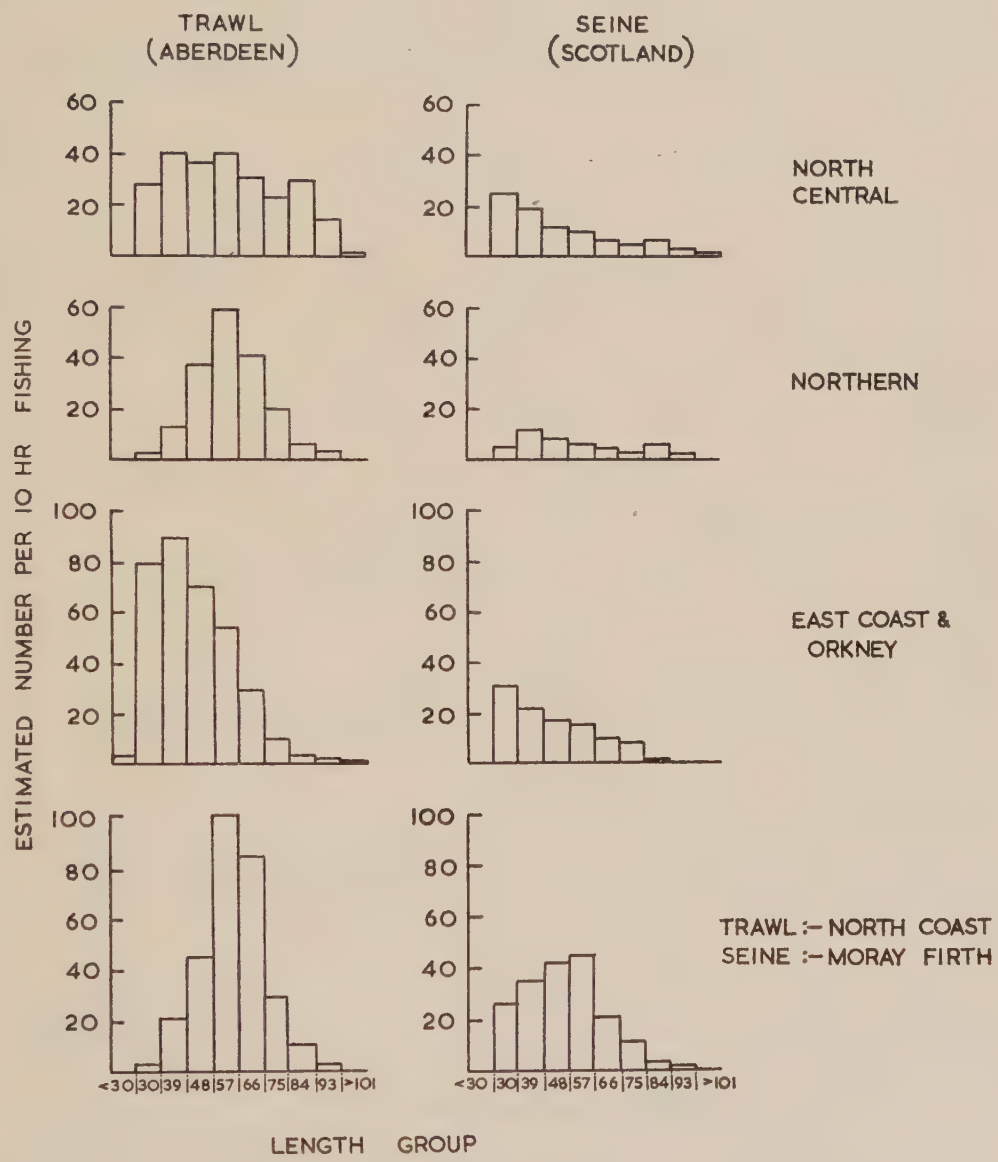


Fig. 11. Length-composition of cod landings from North Sea areas, 1964.

Corresponding data for Aberdeen trawlers are shown in Figure 10 and it is at once apparent that these results are more difficult to interpret. Although the two inshore areas (North Coast and East Coast and Orkney) show peaks in the winter there are in fact more prolonged periods of higher catching rates during the summer months with a peak in June. In the offshore, Northern areas there is a pronounced autumn maximum but in the North Central areas average catching rates fluctuated widely, the highest rates being in June and September.

Earlier investigations of the Aberdeen trawl fishery (Thompson, 1909, 1931) are in general agreement with the above information on the distribution and seasonal variation of the North Sea cod fishery, but as a distinction was made by Thompson between cod and codling a direct comparison is not possible.

LENGTH- AND AGE-COMPOSITION OF THE LANDINGS

The estimated numbers of cod per ten hours' fishing, divided into 9 cm size intervals from inshore and offshore sampling areas in 1964 and 1965, are shown in Figures 11 and 12. From the inshore East Coast and

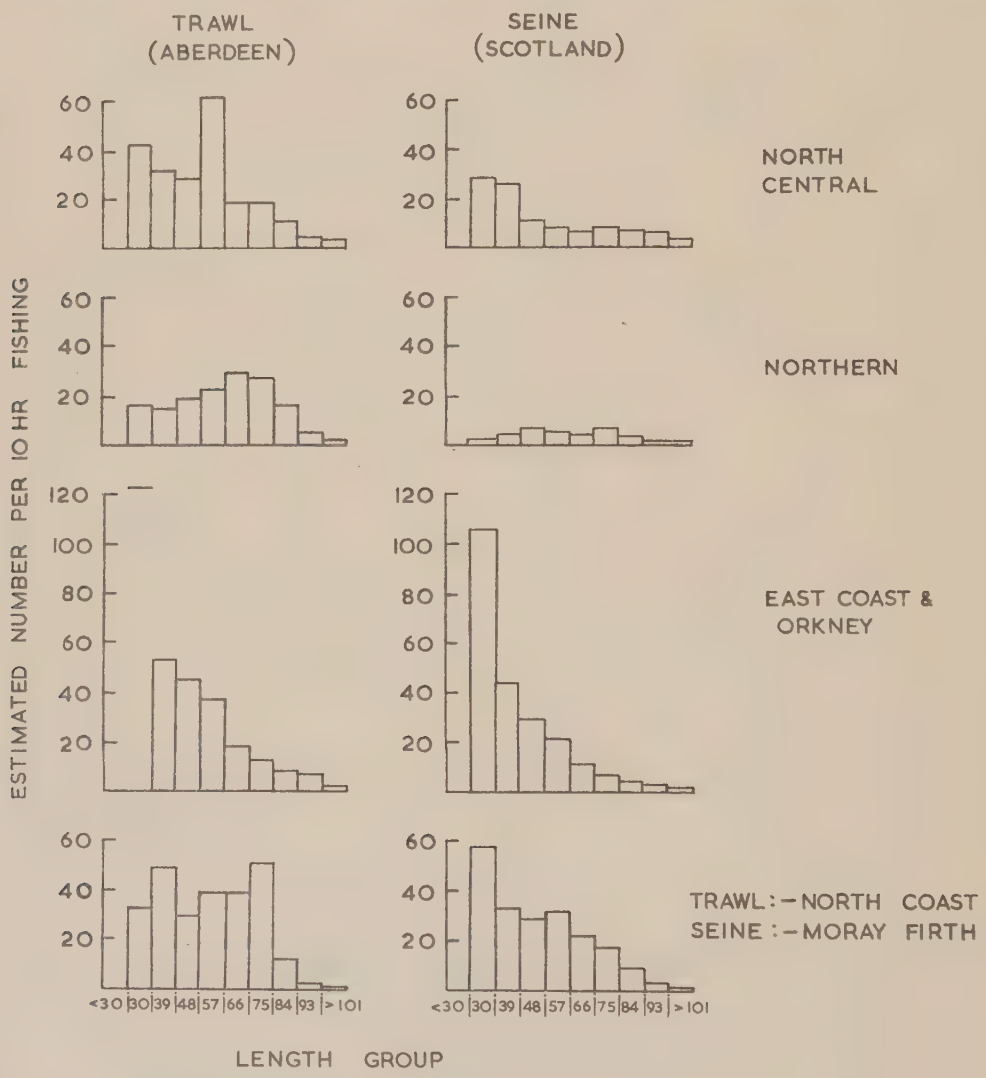


Fig. 12. Length-composition of cod landings from North Sea areas, 1965.

Orkney and Moray Firth areas the bulk of the cod caught were of smaller size (less than 60 cm), but in the samples from the trawl fishery off the North Coast and the trawl and seine fisheries in the Northern and North Central areas the proportion of larger fish was greater.

The annual age-compositions of the cod landings in Scotland from 1963 to 1965 obtained from length-composition data and age/length keys are given in Tables III-V. The most striking feature is the important

TABLE III

NUMBER OF COD OF EACH YEAR-CLASS LANDED PER 10 HOURS' FISHING BY TRAWLERS AT ABERDEEN AND SEINE-NET VESSELS IN SCOTLAND DURING 1963

Year-class	TRAWL				SEINE			
	North Central	Northern	East Coast and Orkney	North Coast	North Central	Northern	East Coast and Orkney	Moray Firth
1962	7·0	1·4	20·0	49·8	0·7	3·2	29·3	13·9
1961	158·1	35·7	405·9	300·9	53·9	44·1	149·7	291·5
1960	59·7	11·8	37·7	41·4	10·0	9·1	28·8	20·6
1959	49·2	27·6	3·7	8·9	5·1	7·2	9·6	5·2
1958	28·1	11·3	2·7	2·2	2·9	4·0	3·3	1·7
1957	3·5	1·4	1·4	1·1	0·7	0·4	1·4	2·7
1956	3·5	0·5	0·6	0·1	0·4	0·2	0·7	0·2
1955	3·5	0·5	0·7	·	0·7	0·4	0·5	0·01
1954 and earlier	0·9	0·5	0·3	0·1	0·1	0·2	0·1	—
Total	312·7	90·4	478·0	405·0	74·3	68·7	223·4	335·8

TABLE IV

NUMBER OF COD OF EACH YEAR-CLASS LANDED PER 10 HOURS' FISHING BY TRAWLERS AT ABERDEEN AND SEINE-NET VESSELS IN SCOTLAND DURING 1964

Year-class	TRAWL				SEINE			
	North Central	Northern	East Coast and Orkney	North Coast	North Central	Northern	East Coast and Orkney	Moray Firth
1963	5·2	3·7	10·6	3·5	1·7	—	13·7	2·1
1962	77·8	61·9	145·0	54·6	37·3	16·7	43·4	60·8
1961	72·6	105·1	141·0	176·7	31·2	16·4	38·3	104·2
1960	20·7	11·7	13·2	16·1	7·4	3·4	10·4	12·9
1959	25·9	3·7	3·8	3·9	5·4	4·4	1·6	2·8
1958	10·4	4·0	1·3	2·2	2·2	1·5	0·4	0·9
1957	—	1·5	0·6	0·9	0·7	0·3	0·1	0·1
1956	—	0·4	0·2	0·1	0·5	0·1	0·01	
1955 and earlier	—	0·4	0·2	0·1	0·2	0·1	—	0·04
Total	212·5	192·2	315·9	258·4	86·5	43·0	108·0	183·9

TABLE V

NUMBER OF COD OF EACH YEAR-CLASS, LANDED PER 10 HOURS' FISHING BY TRAWLERS AT ABERDEEN AND SEINE-NET VESSELS IN SCOTLAND DURING 1965

	TRAWL				SEINE			
Year-class	North Central	Northern	East Coast and Orkney	North Coast	North Central	Northern	East Coast and Orkney	Moray Firth
1964	56·8	28·1	107·2	49·3	8·5	1·8	86·9	63·0
1963	34·3	21·8	102·6	44·6	29·8	3·0	68·6	36·5
1962	87·6	46·5	72·1	67·3	33·8	12·6	43·4	42·3
1961	21·3	38·0	35·3	79·2	17·2	7·8	21·3	52·5
1960	4·1	7·0	8·1	6·2	5·8	3·0	3·0	3·7
1959	7·7	4·4	3·4	1·2	3·3	0·3	1·3	3·0
1958	0·6	2·1	0·8	0·7	1·7	0·4	0·2	0·1
1957 and earlier	1·2	1·5	1·1	0·2	1·4	0·6	0·6	—
Total	213·6	149·4	330·6	248·7	101·5	29·5	225·3	201·1

part that the 1961 year-class has played in all three years and in all areas sampled, firstly as two-years-old fish in 1963, then as three- and four-years-old fish in 1964 and 1965 respectively. The 1963 year-class, which has been so successful in the English cod fishery in the southern North Sea (U.K. Fish Stock Record, 1965), has not appeared prominently in the Scottish landings.

In 1963 and 1964 the cod landings from all market sampling areas showed similar age structures, and it is evident that the fishing by both trawl and seine nets was centred to a large extent on the two- and three-years-old fish while those aged five years and older made up a very small part of the catches. The situation was similar in 1965, but in this year the 1961 year-class, now four years old, provided a good fishery for relatively large cod. In general, the proportion of older fish in the samples from the offshore areas was greater than in those from the inshore areas.

MORTALITY RATES

The data provided by the market sampling programme on the relative abundance of the different age-classes was used for estimating the total mortality coefficient (Z) of the cod stock exploited by the Scottish fishery in the North Sea area. The estimates of Z were obtained by converting the numbers of fish landed in each age-group per unit effort into logarithms, and averaging the differences between the same year-classes in successive years. The estimates obtained are given in Table VI. The one- and two-year-old categories contained individuals which are below the 30 cm minimum permitted landing size and their numbers will have been underestimated, as can be seen from the negative mortality rates obtained. Therefore, the estimation of average mortality rates for the main exploited age-groups was restricted to age-groups three and older.

In general, the values obtained between age-groups in the age-range 3 to 6 were fairly constant for each area. Unfortunately, the trawl data from the North Central area were rather limited and the results from this

TABLE VI

ESTIMATED TOTAL MORTALITY COEFFICIENTS (z) FOR COD

Mean values for 1963–4 and 1964–5

(*a*) from trawl landings

Area / Age (yr)	North Central	Northern	East Coast and Orkney	North Coast
1—2	—1·84	—2·52	—1·82	—1·04
2—3	0·34	—0·75	0·61	0·35
3—4	1·18	0·83	1·48	1·40
4—5	1·22	1·48	1·14	1·96
5+—6+	2·24	0·59	0·91	1·24
Average 3—6+	1·55	0·97	1·18	1·53

(*b*) from seine-net landings

Area / Age (yr)	North Central	Northern	East Coast and Orkney	Moray Firth
1—2	—3·36	—0·81	—1·75	—1·34
2—3	0·30	0·52	0·62	1·04
3—4	0·74	0·60	1·16	1·68
4—5	0·50	0·42	1·72	1·29
5+—6+	0·60	0·56	1·38	1·58
Average 3—6+	0·61	0·53	1·42	1·52

area must therefore be viewed with caution, but it is clear that total mortality rates from the inshore grounds were considerably higher than from those offshore. For seiners the values from the East Coast and Orkney and Moray Firth areas were 1·4 and 1·5 respectively and from the Northern and North Central areas 0·6 and 0·5. The trawl figures do not show quite such a striking difference, but the limitation of some of the offshore data has already been noted.

Apart from the obvious relationship between high total mortality rates and areas of high exploitation, another factor which could affect the values found for any one area is the possible movement of fish into or away from the area. While the length- and age-composition information and the data on seasonal catching rates have already given some indication that there is a movement of older fish into deeper water, this has not so far been demonstrated by the results of tagging experiments (Symonds and Raitt, 1966). Although it cannot be excluded, it seems reasonable to assume that the high total mortality rates for the inshore grounds include

a fairly large component representing fishing mortality and other reductions in total numbers caused by natural deaths and emigration. The high recapture rates of tagged fish from these grounds (up to 60%) provide additional evidence of a high fishing mortality (Symonds and Raitt, 1966).

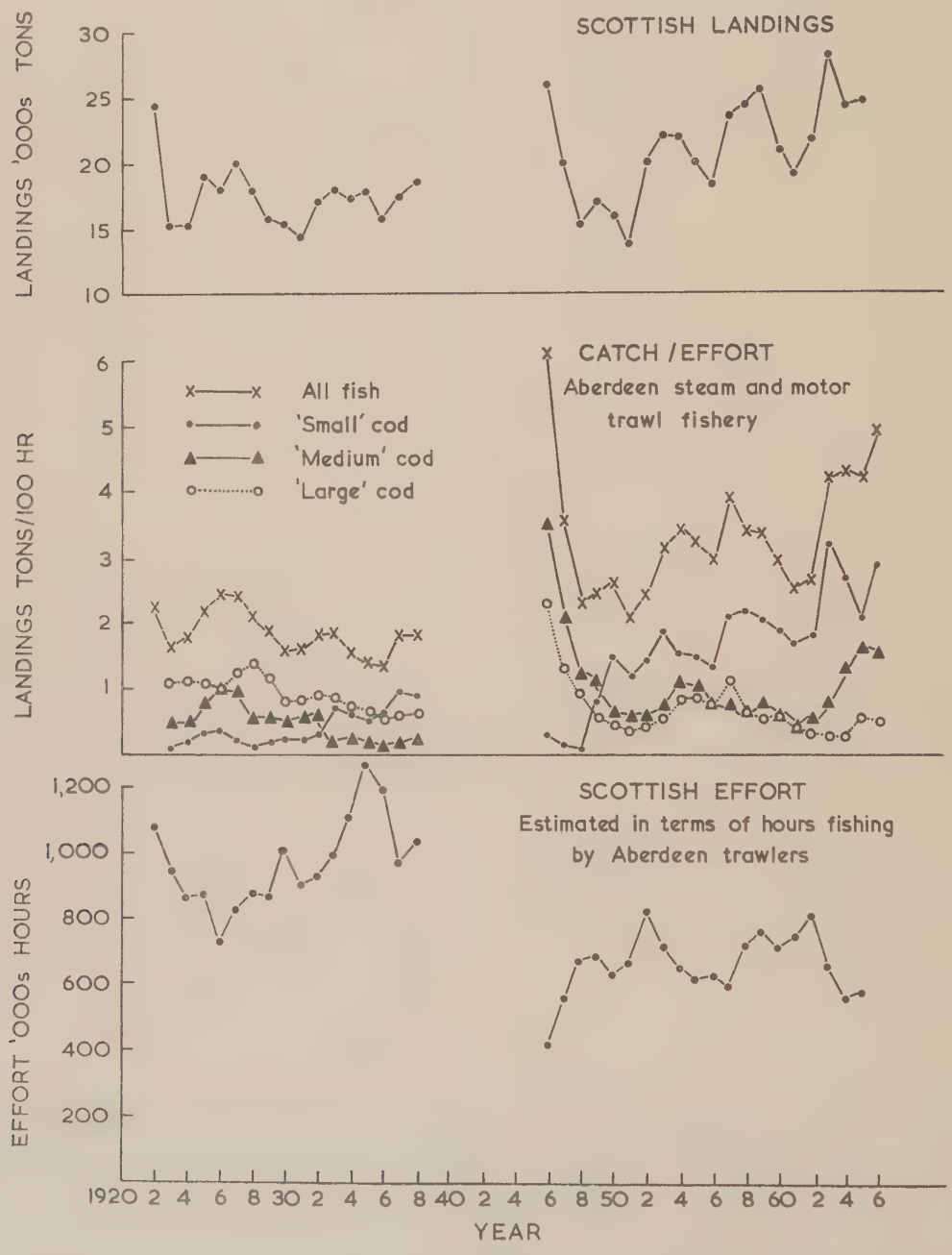


Fig. 13. Statistics of the Scottish cod fishery in the northern North Sea, 1920–1966.

Estimates of the total mortality coefficient for the whole northern North Sea cod stock can be calculated for each year by applying weighting factors to the results from each sampling area according to its surface area

and to the abundance of cod in each area as estimated by the catch per unit effort. The overall estimate from seine-net catches of fish of three years and older is then $Z = 0{\cdot}88$. The figure for trawl catches of $Z = 1{\cdot}30$ is perhaps unduly influenced by the high estimate for the North Central area.

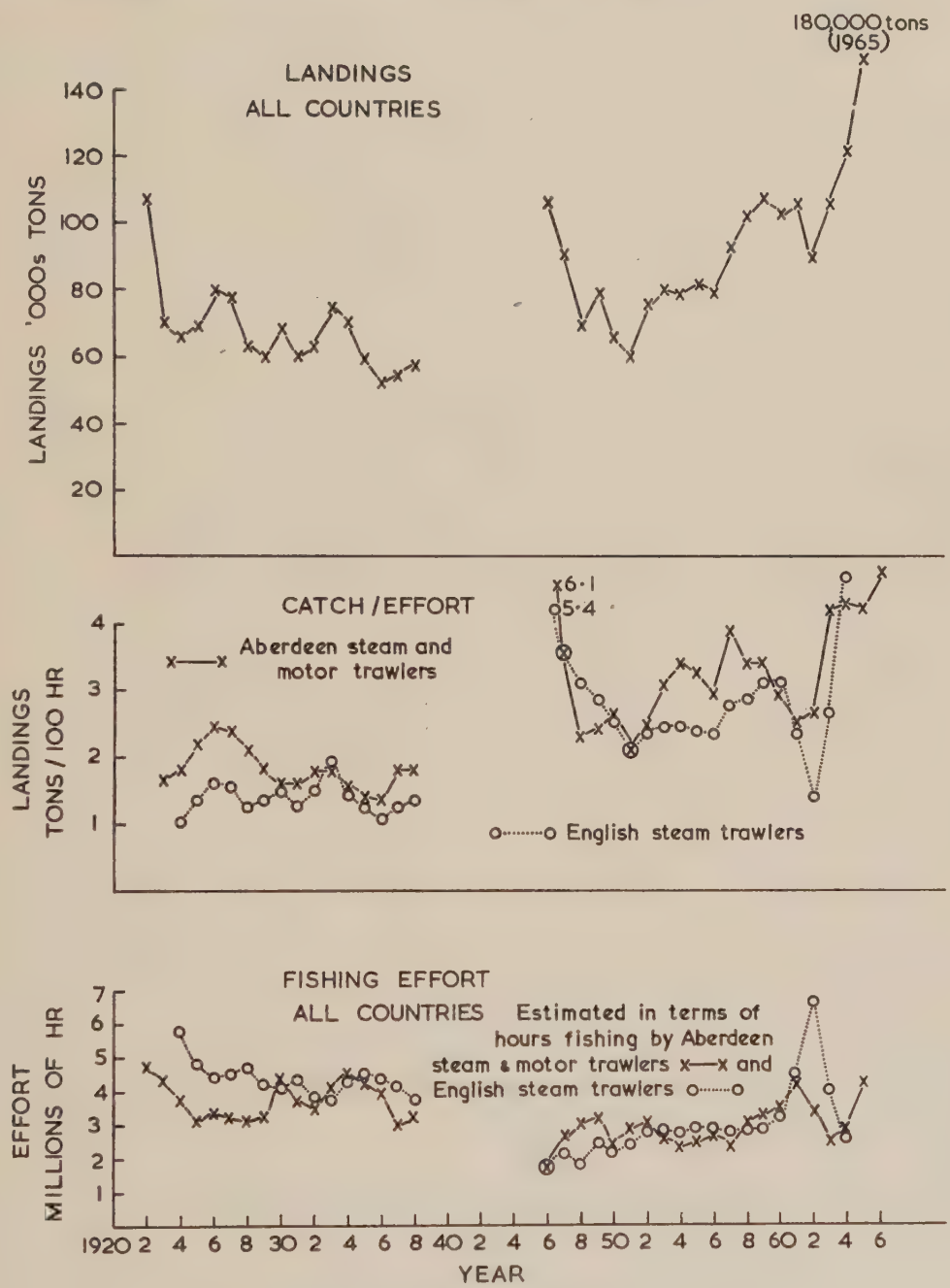


Fig. 14. The total North Sea cod fishery, 1920–1965.

LONG-TERM FLUCTUATIONS IN THE FISHERY

The statistics of the Scottish cod fishery in the northern North Sea since 1922 are given in Figure 13 The total landings are those by all fishing methods combined (data from Scottish Sea Fisheries Statistical

Tables), the catch per unit effort refers to the Aberdeen trawl fishery and the total fishing effort has been derived in terms of hours fishing by Aberdeen trawlers.

In the pre-war period (1922-1938), annual catches were fairly steady between 15 and 20 thousand tons and the estimated fishing effort increased from 730,000 hours in 1926 to over 1,250,000 hours in 1935, while the catch per unit effort decreased steadily though slightly throughout this period. After the war the landings dropped to a minimum of 14,000 tons in 1951 but thereafter increased to a level substantially above the pre-war average (20,000—25,000 tons). The estimated fishing effort, between 600,000 and 800,000 hours, remained much lower than pre-war, while the catch per unit effort, after an initial post-war decline until 1951, showed an irregular increase up to the present.

The pre-war Scottish data, then, are in agreement with expectations from fishing theory where, in a fishery where total effort goes up and the catch remains steady, the catch per effort shows a small but significant decrease. The situation for the post-war fishery, however, is completely different. Landings and catch per unit effort have both increased during this period, while effort has remained fairly steady. In fact the present level of exploitation provides the highest catch per unit effort figures for the whole period with the exception of the war and immediate post-war years.

The statistics of the overall North Sea cod fishery (catch, effort and catch per unit effort) by all countries were presented in the U.K. Fish Stock Record for 1961. In that report the catch per unit effort was derived from the English trawl fishery and the total fishing effort for the North Sea was estimated in terms of hours fishing by English steam trawlers. This information is given in Figure 14. English steam trawl data are available only to 1964 since North Sea effort by this method had dropped to only 3,600 hours. The corresponding estimates for Scottish trawler units are also given for the whole period; these represent steam and motor trawl combined. The estimated trends in catch per unit effort and overall effort by the two methods are in fairly close agreement. The pre-war period, however, was marked by falling catches and fishing effort while the catch per unit effort remained relatively steady. In the post-war period the pattern was generally the same as for the Scottish fishery in the northern North Sea, the catches increasing markedly and the fishing effort and catch per unit effort tending to increase during the 1950s. Of particular interest is that in both the Scottish fishery (Fig. 13) and the fishery by all countries (Fig. 14) the average post-war fishing effort has been substantially lower than before the war, and the total landings and catch per unit effort higher. It was concluded in the 1961 Fish Stock Record report that there had been a conservation effect in relation to the lower fishing intensity, resulting in an increase in the average size and age of the fished stock.

Unfortunately no data on the length- and age-compositions of the Scottish cod catches during the pre-war and post-war periods up to 1963 are available from which to judge such an effect in the northern North Sea. However, data on the catches of cod in the 'small,' 'medium' and 'large' market categories are available. These are shown in Figure 13 together with the overall catch per unit effort for the Aberdeen trawl fishery for cod. Before the war the catches on average contained a high proportion of 'large' and 'medium' cod although by 1939 more 'small' fish were appearing in the landings. In fact 'large' and 'medium' fish had been diminishing slightly but steadily since 1928. Immediately after the war, the catch per unit effort was very high in association with the accumulation of the larger categories of cod during the war-time period of low fishing effort, as was shown for the English trawl fishery for cod by Margetts and Holt (1948). In the years 1946-1951 the catches of larger cod decreased rapidly; they increased again from 1951 to 1954 but then they again declined steadily. In contrast, the catch per unit effort of 'small' cod increased greatly throughout the post-war period. The available evidence suggests that the size-composition of cod in the category 'small' (fish up to about 55 cm in length) on the Aberdeen market has not changed appreciably during the period in question, so it is unlikely that the increase in 'small' cod and decrease in the 'large' cod can be accounted for by changes in the market categories. In fact, the data indicate that the increase in landings and catch per unit effort of the Scottish trawl fishery in the 1950s can be attributed entirely to an increase in the catch per unit effort of the smaller sizes of cod, while the stock of larger fish has declined.

The high figures for 'small' cod in 1963 and 'medium' in 1964 and 1965 coincide with the entry into the fishery of the strong 1961 year-class.

THE PRESENT STATE OF THE FISHERY

Information is presented above on the Scottish cod fishery, its relative importance, distribution and seasonal fluctuations. Recent data on the relative abundance of year-classes of cod in the Scottish and English fisheries suggest that the stocks exploited by the two fleets may be quite distinct (U.K. Fish Stock Record, 1965). Whereas the successful 1961 year-class dominated the Scottish fishery in 1963 and 1964, it was not particularly strong in the southern North Sea. In contrast, the very good 1963 year-class recruited to the English fishery in 1965 is not evident in the catches of the Scottish fishery. The apparent separation of the stocks fished by these two fisheries is supported by the complete lack of evidence of any significant interchange of tagged fish between the northern and southern North Sea (Symonds and Raitt, 1966; Bedford, 1966). It seems clear that if a year-class is particularly abundant in one of these areas its effect will, subsequent to its reaching commercial size, usually be confined to that area.

Undoubtedly the most striking and important fact produced by the present analysis has been the way in which the composition and abundance of the Scottish cod stock has changed during the pre-war and post-war periods. The available data indicate that, after the war, the total fishing effort in the northern North Sea has been substantially less than before the war and that, since 1956, catches have increased greatly. The increase in landings can in general be attributed to a rise in the catch of 'small' cod per unit effort; at the same time there has been a decline in the catch of the larger cod per unit effort. If the increase in catch was a direct result of the reduction in fishing effort it would be expected to be reflected in an increase in the relative proportions of the 'medium' and 'large' cod over the small fish, as was evident in the immediate post-war years following the large, war-time reduction in fishing effort. That this is not evident in the more recent years suggests that some factor other than the amount of fishing has affected the composition and abundance of the cod stock. One possibility is that there has been a considerable increase in recruitment to the northern North Sea stock with a corresponding increase in the natural mortality rate compared with the pre-war years. Unfortunately no data are available from the Scottish fishery on pre-war mortality rates, but Graham (1934) provides figures for the abundance of cod age-groups in the southern and central North Sea for 1930-1932 which give estimates of Z of about 0·6—0·7. These are rather lower than the values obtained in the present report for seiners and considerably lower than those for trawlers but, as already discussed, the southern North Sea stock is probably quite distinct from that in the northern North Sea.

Increased market demands for smaller fish have evidently been partly the reason for the increased codling catches. The Scottish fishermen now retain many small fish which previously would have been rejected at sea, and with refinements in fishing gear are able to exploit more productive fishing grounds. There is also the possibility that they now seek the smaller categories—in the past they tended to avoid them in favour of the larger fish—although this would be difficult to demonstrate. However, there is no evidence that there has been any major change in the distribution of fishing since the war by either the Scottish seine-net or trawler fleet, except in the North Central trawl fishery where there appears to have been a gradual decline in effort with a corresponding drop in landings (see Table I). It seems likely, then, that the decrease in the catch per unit effort of the larger categories reflects a steady post-war decline in their abundance and/or availability on the traditional fishing grounds in the northern North Sea. It is not clear to what extent this is due to the effects of fishing, or to changes in the distribution of the fish or to other biological factors. In some respects this is analogous to the changes in the northern North Sea autumn-spawning herring stocks over the same period (I.C.E.S. 1966). It is significant that the cod fishery in recent years has been dependent mainly on young fish and that mortality rates estimated from market samples are relatively high, suggesting that the North Sea cod stock fished by Scottish vessels is fairly heavily exploited. There is, however, the evidence of the steady increase in total landings over this period compared with the corresponding pre-war years, associated with a reduction in fishing effort. This has resulted in a high catch, consisting mainly of small fish, per unit effort. That this is a direct result of better recruitment to the fishable stock in the period 1950-65 is considered by the authors to be the best, if not the only, method of accounting for the facts.

SUMMARY

A summary is made of the importance of the Scottish North Sea cod fishery. Approximately a half of all the cod landed in Scotland comes from the North Sea. When the values of the North Sea landings of different fish species are considered in recent years, cod is seen to be the second most valuable fish landed. Scotland's share of the total catch of cod from the North Sea by all countries is about 30%. Landings by trawlers have, on the whole, been smaller after than before the Second World War, whereas landings by seiners have shown a marked increase, and since 1955 they have exceeded those of the trawlers from North Sea grounds.

The Marine Laboratory's market sampling programme is described, and the spatial and seasonal distribution of the seine and trawl fisheries for cod are compared. The length- and age-composition etc. of the landings in recent years are given, and mortality rates are derived from this information.

The history of the Scottish North Sea cod fishery before and after the war is reviewed and the present state of the fishery is discussed. Pre-war data show that the total effort rose during this period, the landings remained fairly steady and the catch per unit effort declined slightly. Since the war, however, landings and catch per unit effort have both gone up while effort has remained fairly steady. In fact the present level of exploitation represents the highest catch per unit effort figures for the whole period under review with the exception of the war and immediate post-war years. Increased total cod catches in recent years have consisted mainly of small fish and are considered to represent a direct result of better recruitment to the fishable stock in the period 1950-65.

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